CHAPTER 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Theoretical Background

2.1.1 Definition and Classification of Hazardous Waste

The term "hazardous waste" means a solid waste or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristic may cause the following effect:

1) It may cause or significantly contribute to an increase in mortality or increase in serious irreversible, or incapacitating reversible, illness: or

2) It may pose a substantial present or potential hazard to humanhealth or the environment when improper treated, stored, transported, or disposed of, or otherwise managed.

There are three ways that a certain waste can be considered a "Hazardous" waste. They are:

1) The waste is specifically list in the regulations. For example, listof toxic or dangerous substances and materials that require priority consideration or should be controlled according to international agreement are shown in Table 2.1 and 2.2.

2) The waste is tested and meets one of four characteristics, i.e.ignitable, corrosive reactive, or toxic.

3) The waste is declared hazardous by the generator (the entity producing the waste), base on its knowledge of the waste.

TABLE 2.1 List of Toxic or Dangerous Substances and materials Selected as Requiring Priority Consideration

ITEM	SUBSTANCES AND MATERIALS
1	Arsenic and compounds
2	Mercury and compounds
3	Cadmium and compounds
4	Thallium and compounds
5	Beryllium and compounds
6	Chromium (VI) compounds
7	Lead and compounds
8	Antimony compounds
9	Phenolic compounds
10	Cyanide compounds
11	Isocyanates
12	Organohalogenated compounds, excluding inert polymeric materials and other substances referred to in this list or covered by other directives concerning the disposal of toxic and dangerous waste
13	Chlorinated solvents
14	Organic solvents
15	Biocides and phytopharmaceutical substances
16	Tarry materials from refining and tar residues from distilling
17	Pharmaceutical compounds
18	Peroxides, chlorates, perchlorates and azides
19	Ethers
20	Chemical laboratory materials, not identifiable and/or new, with unknown effects on the environment
21	Asbestos
22	Selenium and compounds
23	Tellurium and compounds
24	Polycyclic aromatic hydrocarbons (carcinogenic)
25	Metal carbonyls
26	Soluble copper compounds
27	Acids and/or basic substances used in the surface treatment and finishing of metals

TABLE 2.2 Categories of Waste to be controlled under the basal Convention

ITEM	CATEGORIES OF WASTE
Y1	Clinical waste from medical care in hospitals, medical centers and clinics.
Y2	Wastes from the production and preparation of pharmaceutical products.
Y3	Wastes pharmaceuticals, drugs and medicines
Y4	Wastes from the production, formulation and use of biocides and phytopharmaceutical.
Y5	Wastes from the manufacture, formulation and use of wood preserving chemicals.
Y6	Wastes from the production, formulation and use of organic solvents.
Y7	Wastes from heat treatment and tempering operations containing cyanides.
Y8	Waste mineral oils unfit for their original intended use.
Y9	Waste oils/water, hydrocarbon/water mixtures, emulsions.
Y10	Waste substances and articles containing or contaminated with polychlorinated biphenyls (PCBs) and/or polychlorinated terphenyls (PCTs) and/or polybrominated biphenyls (PBBs).
Y11	Waste tarry residues arising from refining, distillation and any pyrolytic treatment.
Y12	Wastes from production, formulation and use of inks, dyes, pigments, paints, lacquers, vanish.
Y13	Wastes from production, formulation and use of resins, latex, plasticizers, glues/adhesives.
Y14	Waste chemical substances arising from research and development or teaching activities which are not identified and/or are new and whose effects on man and/or the environment are not known.
Y15	Wastes of an explosive nature not subject to other legislation.
Y16	Wastes from production, formulation and use of photographic chemicals and processing materials.
Y17	Wastes resulting from surface treatment of metals and plastics.
Y18	Residues arising from industrial waste disposal operations.
	Waste having as constituents-
Y19	Metal carbonyls.
Y20	Beryllium; beryllium compounds.
Y21	Hexavalent chromium compounds.

ITEM	CATEGORIES OF WASTE
Y22	Copper compounds
Y23	Zinc compounds.
Y24	Arsenic; arsenic compounds
Y25	Selenium; selenium compounds.
Y26	Cadmium; cadmium compounds.
Y27	Antimony; and antimony compounds.
Y28	Tellurium; tellurium compounds.
Y29	Mercury; mercury compounds.
Y30	Thallium; thallium compounds.
Y31	Lead; lead compounds.
Y32	Inorganic fluorine compounds.
Y33	Inorganic cyanides.
Y34	Acidic solutions of acids in solid form
Y35	Basic solutions of bases of in solid form
Y36	Asbestos
Y37	Organic phosphorous compounds.
Y38	Organic cyanides
Y39	Phenols; phenol compounds including chlorophenols.
Y40	Ethers.
Y41	Halogenated organic solvents.
Y42	Organic solvents excluding halogenated solvents.
Y43	Any congener of polychlorinated dibenzo-furan
Y44	Any congener of polychlorinated dibenzo-p-dioxin.
Y45	Organohalogen compounds other than substances referred to in this Annex. (E.g. Y39, Y41, Y42, Y43, Y44)

A waste may be considered hazardous if it exhibits any **one** of the following characteristics:

1) *Ignitable wastes* are liquids with a flash point below 60°C, or solids capable of causing fire under standard temperature and pressure.

2) *Corrosive wastes* are aqueous wastes with a pH below 2 or above 12.5, or which corrode steel at a rate in excess of 0.25 inches per year.

3) *Reactive wastes* are normally unstable; react violently with air or water, or from potentially explosive mixtures with water. This category also includes wastes that emit toxic fumes when mixed with water and materials capable of detonation.

4) *Toxicity* is the characteristic to determine whether toxic constituents in a waste sample will leach from the waste if it is to be disposed of by landfill method.

2.1.2 Present Situation of Hazardous Waste Management in Thailand

As Thailand comes into the world of semi-industrialized country, industrial waste amount have also been increased in a rapid pace. Typical industrial wastes generated as by-products include heavy metal sludge, pesticide ingredient, strong spent acids, off spec dry batteries. The amount of such by-products in 1996 was estimated to reach at 1.6 million tons (Table 2.3, 2.4). Majority of generated wastes is not yet proper handled, causing potential hazard to the environment.

The Ministry of industry has established a standard for hazardous waste identification and regulation requiring proper treatment and disposal in 1992, as notification under the Factory Act. In 1997, the Ministry promulgated again a new standard for industrial hazardous waste identification with general guideline for treatment and disposal methods. This new law requires that waste generators have to report to the Department of Industrial Works the types and quantities of wastes generated and the treatment and disposal procedures applied

The government has planned to set up several treatment centers and disposal sites to accommodate the identified wastes. The first treatment plant was built in Bangkok in 1998, called "Samae-dam Center". First secure landfill was built a few years later, called "Ratchburi Center" in Ratburi Province.

TABLE 2.3 Total Hazardous Waste Quantities in Thailand by Category and Year

Type of Waste	Waste Quantity (Tons / year)		
	1991	1996	2001
Waste Oil	188,254	322,779	589,508
Organic Liquid	311	522	876
Organic Sludges and Solids	6,674	11,951	21,533
Inorganic Sludges and Solids	19,163	31,850	53,696
Heavy Metal Sludges and Solids	536,322	946,565	1,658,192
Solvents	36,163	66,532	124,306
Acid Wastes	31,432	53,793	96,105
Alkaline Wastes	9,839	16,846	29,019
Off-spec Products	25	52	107
Aqueous Organic Wastes	242	499	1,037
Photo Wastes	16,348	30,398	57,809
Municiple Hazardous Wastes	11,787	19,090	31,093
Hospital Wastes	**76,078**	**123,219**	**200,699**
Total	932,638	1,634,104	2,813,980

TABLE 2.4 Total Hazardous Waste Quantities in Thailand by Type of Activity

Type of Waste	Waste Quantity (Tons / year)		
	1991	1996	2001
Manufacturing	157,058	272,272	433,609
Coal and Lignite	1,278	1,854	2,477
Petroleum	3,914	7,032	11,813
Metal Smelting	521,508	922,893	1,620,190
Gommerce/Service	78,497	141,681	257,689
Harbour/Shipping	75,849	134,228	235,644
Hospital/Laboratory	76,078	123,219	200,699
Community	11,787	19,090	31,093
Agriculture	6,687	11,835	20,776
Total	932,638	1,634,104	2,813,980

The Ministry also jointly invested with the private sector to build landfill treatment facility in Mab-Ta-Pud Industrial Estate in Rayong Province, which began its operation in 1997.

1) Samae-dam Center and Ratchburi Center

The Department of industrial Works established a central treatment plant for hazardous waste in 1988 in western suburb of Bangkok. The plant can treat inorganic acid/ alkaline aqueous waste of about 200tons/day, 800tons/days of textile dyeing wastewater, and 200 tons/day of inorganic heavy metal sludge and solids. Nowadays, the plant is operated by a private company (GENCO) and it is treating wasres for about 500 factories, for difference types as follow;

- Spent Acids:	8,500
- Acid/alkaline Waste with Heavy Metals	60,000
- Heavy Metal Sludge and Solids	14,200

The stabilized dry sludge and solids from samae-dam plant are then transported to the Ratchburi Center 140kilometers westwards for landfill.The Ratchburi landfill center was built a few years after the sanae-dam plant. It is located in Ratchburi Province, with an area of about 48 hectares. The secure landfill quality is equivalent to international standard with double high-density polyethylene (HDPE) lining. The Ratchburi Center is now receiving about 30,000 tons/year of waste from Samae-dam plant.

2) Mab-Ta-Pud Center

The Ministry of industry has jointly invested with a private frim to estsblish a private company called "General Environmental Conservation Company Limited (GENCO)" with the intention to set up central treatment and landfill for hazardous waste with a capacity of 1,000 tons/day to serve the industry.

GENCO has planed to build an integrated hazardous waste treatment and disposal system at Pluak-Daeng District in Rayong Province within area of 160 hectares. However, local people due to NIMBY problem (Not In My Back Yard) had rejected the project. Hence, GENCO has moved the project site into Mab-Ta-Pud Industrial Estate in Rayong Province, employing an area of 10 heatares. The center has been operating since mid 1997 with factories of waste stabilization, landfill and fuel blending.

GENCO project's first phase in Mab-Ta-Pud, which cost 950 million bath, has the following capacity:

-Stabilization and Landfill		550 tons/day
	or	137,500 tons/year
-Fuel Blending System		100 tons/day
	or	25,000 tons/year
-Total		650 tons/day
	or	162,000 tons/year
		(8 hrs/day 250 days/year)

The facilities have been completed and have been giving service to the industry since May 1997. In 1997, the Mab-Ta-Pud Center received about 24,000 tons of wastes or average of 145 tons/day (22% of total capacity) for treatment.

The secure landfill occupies 2,705 rai of land (4.4hectares), which has been designed to landfill 250,000 tons (average of 120 tons/day), occupying already about 8% of the available land. The expansion project for landfill involves a piece of land of 150 rai (24 hectares). The new landfill project will be able to hold 1.5 million tons of wastes or for another 50 years of operation at present rate of 120 tons/day.

GENCO has also plans for the second and third phases for chemical-physical treatment and incineration, being budgeted at 400 million bath and 1,050 million bath, respectively. The second phase chamical-physical unit will have a capacity of 250 tons/day or 62,500 tons/year scheduled to be operational in 1999. The third phase incineration unit will have a capacity of 100 tons/day or 25,000 tons/year also scheduled to be operational in 1999.

2.1.3 The Hierarchy of Hazardous Waste Management

For any particular hazardous waste stream (i.e. type and quantity), it is possible to define a hierarchy of preferred management options, which should be considered in turn, the objective being to limit as far as possible the quantity of hazardous waste requiring final disposal. In general, the sequence will be:

1) Waste avoidance or reduction at source

The reduction or elimination of hazardous waste at the source is usually within aprocess. Source reduction measures include process modification, feedstock substitutions, and improvement in feedstock purity, housekeeping and management practice changes, increases in the efficiency of equipment, and recycling with a process.

2) Recycling or resource recovery

Recycling is the use or reuse of hazardous waste as an effective substitute for acommercial Product: or as an ingredient or feedstock in an industrial process. It includes the reclamation of useful constituent fractions within a waste material or the removal of contaminants from a waste to allow it to be reused.

3) Treatment of waste

Treatment is defined as any method, technique, or process, which changes the physical, chemical, or biological characteristics of hazardous waste by physical, chemical, or biological means to destroy, convert or immobilize hazardous constituents .It might make the waste to be non-hazardous, less hazardous, safer to manage, amendable for storage, or reduce in volume.

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World-War II material scarcity and (4) a tradition of a high level of cooperation between government and industry in all areas of technology and industrial policy. There seems to be general agreement that the heavily industrialized nations of Western Europe have been quicker to adopt hazardous waste reduction strategies, such as source separation, process modification, end-products substitution, and recycling.

The sophistication of European countries in matters of hazardous waste disposal may be overstated in some instances. For example, the British have deliberately mixed hazardous wastes with conventional MSW in permeable landfills. The belief is that the toxic chemicals will be converted to nontoxic forms through leaching and biological degradation (Piasecki and Brooks, 1987). Many in the field of waste management in Europe and the United States disagree with this co-disposal approach to hazardous waste management. Comparing nations with respect to their approaches in dealing with complex environmental issues such as hazardous waste management is difficult at best. There is no agreement on which chemical substances are toxic. In addition, a unanimous agreement on the best approach to treatment and ultimate disposal dose not exist. European countries and Japan use incineration for disposal extensively, while the United States continues to emphasize the land disposal option.

The high cost of hazardous waste management encourages international businesses to locate manufacturing plan that produce hazardous waste in countries with less stringent disposal regulations. This issue was raised prior to the passage of the North American Free Trade Agreement (NAFTA) by the United States, Canada and Mexico in 1994. The financial motivations for generators to expert hazardous waste to third world countries, which lack sufficient management regulation, are substantial.

The need for a hazardous waste management system begins directly upon generation of waste and continues through all subsequent stage to final treatment and disposal. The cradle-to-grave principle of hazardous waste management is shown in figure 2.2. This system is really a series of management actions to control and contain the waste coordination among various persons and groups of persons. In this simplest form a hazardous waste management system consists of three units:

1) Waste storage upon generation

2) Waste collection and transportation

3) Final treatment and disposal of waste

The following describes the elements of an overall management system that can be applicable to on-site and off-site management of hazardous waste.

2.1.4.1 Waste storage upon generation

The final stage in the waste generation stage is storing of waste. The waste generator needs to have a system to safely store waste until it can be transferred for further storage, treatment or disposal. Typically, this storage is done in containers or bulk tanks. The methods used depend largely on how and where the waste is generated and the physical state of the waste.

i) Containers

Containers offer the advantages of being varied portable, suitable for any physical state of waste, and flexible as to means of filling. They can be kept next to the waste generating process until full, then easily moved to a waste storage area awaiting further transfer

Most containers are suitable for many types of waste, from liquids, sludge to bulky solids. Containers may be filled by any available method, for example, pumping, shoveling, or tipping. Empty containers, which had been used for storage of raw material, may be suitable for storing waste, depending on the compatibility of waste with the container and with any residues, which may leave in the container. Compatibility with the container is important so that the container's integrity is not impaired. For example, a plastic container should not be used to store solvent waste. Care must be taken those residues from the containers previous contents will not react with the waste; for example, the container contained cyanide salts should not be used for waste acid.

Disadvantages of containers are that they are easily damages and toppled. Because they are easily moved and stacked, they accumulate easily and may lead to over-storage at the waste producer's site. Large groups of stacked containers are also difficult to inspect for leaks and spills.

ii) Tanks

Tanks are useful for accumulating wastes that are easily handles by bulk material handling systems such as pipelines, shuts, or belt conveyor. Tanks offer more rigid and integral containment than containers and are easier to inspect for leaks and spills. Proper containers used for storage of different type of hazardous waste are shown in Table2.5.

2.1.4.2 Collection/Transportation

i) Packaging/Labeling

All containers or tanks containing waste destined for transportation should be clearly labeled with the type of waste and its hazards. The packaging should be secure enough to prevent leaks, spills, and vaporization during transport.

ii) Paper Work Tracking System

Many countries have adopted a paperwork tracking or manifest system to document the generation of a hazardous waste, all the latter processes that it may go through, and off-site waste transportation. The paper work accompanies the waste shipment and provides a record of waste movement from the waste producer through each intermediate management stage to final treatment and disposal. The paper work serves as a "chain of custody" document. Every time the waste shipment changes hands, the responsible person sign the paper work. Often the government regulatory agency must receive a copy of the paper work at crucial stages in the transfer to monitor the transfer.

iii) Direct Transfer/Collection Station

Waste may be transferred off-site either directly or via a collection or transfer station. Direct transfer is economical if a large enough shipment can be sent from a single waste producer, or if a truck picks up waste from more than one waste producer.

iv) Transportation

The most common means of transportation of hazardous chemical waste is by road. Hazardous associated with on and off-loading activities pose a greater risk than the transport itself. Provided trained drivers in reliable vehicles are employed, and waste is properly packaged, the risks to the community are small. But the transport risks should be assessed. The following controls are desirable

2.1.4.3 Hazardous waste Treatment Technology

Many different treatment technologies can be used prior to ultimate disposal. Their aims are modification of the physical and/or chemical properties of the waste. They reduce volume, immobilize toxic components or detoxify. The choice of the best practicable way of treating a given waste depend on many factor, including the availability and sustainability of disposal or treatment facilities, safety standards, and cost considerations. No disposal route offers absolute safety, and any waste treatment or disposal technology has an associated level of risk.

TABLE 2.5 Containers used for storage of hazardous waste

Waste Category	Container		
	Type	**Capacity (m^3)**	**Auxiliary equipment and conditions of use**
Radioactive substances	Lead encased in concrete Lined metal drum	Varies with wastes 0.21	Isolated storage buildings; Special container markings; high capacity hoists and lighting equipment
Toxic chemicals	Metal drums Lined metal drum storage tanks	0.21 0.21 19	Special blending precautions to prevent hazardous reactions; washing facilities for empty containers
Biological wastes	Sealed plastic bags	19	Heat sterilization prior to bagging; special heavy duty bags with hazards warming printed on sides
Flammable wastes	Metal drum Storage tank	0.21 19	Fume ventilation; temperature control
Explosive	Shock absorbing containers	varies	Temperature control; special container marking

2.1.5 Waste minimization

"Waste Minimization" means the reduction to the extent feasible, of hazardous waste that is generated prior to treatment, storage and disposal. It is defined as any source reduction or recycling activity that results in either (1) reduction of the total volume of hazardous waste, (2) reduction of the toxicity of the hazardous waste, or (3) both. Practices that are considered waste minimization include recycling, source separation, product substitution, manufacturing process changes, and the use of less toxic raw materials.

This program will include a step-by-step analysis of waste reduction options, and recycling options. Waste minimization options can include but are not limited to the following options:

- Good Operating Practices

  These practices involve the procedural or organizational aspects of the university's operations, research or teaching activities and in some areas changes in operating practices, in order to reduce the amount of waste generated. These practices would include, at a minimum, material handling improvements, scheduling improvements, spill and leak prevention, preventive maintenance, corrective maintenance, material/waste tracking or inventory control, and waste stream segregation according to toxicity, type of contaminant and physical state.

- Material Substitution Practices

  The purpose of these practices is to find substitute materials, which are less hazardous than those currently utilized and which result in the generation of waste in smaller quantities and/or less toxicity.

- Technological Modification Practices

  These practices should be oriented towards process and equipment modifications to reduce waste in the university setting. These practices can range from changes that can be implemented in a matter of days at low cost, to the replacement of process equipment involving large capital expenditures.

- Recycling Options

  These options are characterized as use/reuse and resource recovery techniques. Use and reuse practices involve the return of a waste material either to the originating process or to another process as a substitute for an input material. Reclamation practices tenders a waste to another company.

- Surplus Chemical Waste Exchange Options

  Inter- and intra-department chemical exchange has been implemented and encouraged by faculty and staff. A material exchange not only reduces wastes, it also saves money, both important considerations during times of fiscal crises.

2.1.6 Hospital Waste

Hospital waste is generated during the diagnosis, treatment, or immunization of human beings and animals; in research activities in these fields or in the production; or testing of biologicals. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. These are in the form of disposable syringes, swabs, bandages, body fluid, human excreta, etc. Hospital waste can be classified into 3 categories. They include household wastes or domestic solid wastes, infectious wastes or medical wastes, and hazardous wastes. Household wastes or domestic solid wastes include uninfected food waste, fruit, vegetable and kitchen waste. Recyclable materials include uninfected paper, cardboard, glass, plastic having no risk. Infectious waste includes pathogenic and nonpathologic, infective, chemical and pharmaceutical waste and cutting and pierced materials and pressed container generated from clinic and polyclinic (recyclable matter sourced from clinic and polyclinic; and all medical waste including illness risk) were evaluated as medical waste. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4kg of waste generated in a hospital at least 1kg would be infected. Hospital waste contaminated by chemicals used in hospitals is considered hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants; and mercury, which is used in thermometers or equipment that measure blood pressure. Most hospitals in Thailand do not have proper disposal facilities for these hazardous wastes. Waste generation depends on numerous factors such as established waste management methods, type of health-care establishment, hospital specializations, proportion of reusable items employed in health care, and proportion of patients treated on a day-care basis. In middle and lowincome countries, health care waste generation is usually lower than in high-income countries. The amount of radioactive health care waste is generally extremely small compared with the radioactive waste produced by the nuclear industry. Developing countries are producing very small quantity of health-care waste comparing developed countries like United States of America.

2.1.6.1 What are the classifications and categories of hospital waste?

Medical waste means any waste generated in the diagnosis, treatment or immunization of human beings or animals, in research pertaining in the biological test.

Health-care waste includes all the wastes generated by the laboratories, research centers besides the hospitals and clinics. 75% to 90% of the wastes produced by the health-care establishments are non-risk or general comparable to domestic waste. The rest 10% to 25% of the waste is regarded as hazardous waste, which may create variety of risks. The following table will show the categories and classification of hazardous waste.

1) Infectious waste

Infectious waste is suspected to contain pathogens (bacteria, viruses, parasites or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts. This category includes:

- Culture and stocks of infectious agents from laboratory work;
- Waste from surgery and autopsies on patients with infectious diseases (e.g. tissues and materials or equipment that have been in contact with blood or other body fluids)
- Waste that has been in contact with infected patients undergoing haemodialysis (e.g. dialysis equipment such as tubing and filters, disposable towels, gowns, aprons, gloves and laboratory coats)
- Infected animals from laboratories

- Any other instruments or materials that have been in contact with infected persons or animals.

Cultures and stocks of highly infectious agents, wastes from autopsies, animal bodies and other waste items that have been inoculated, infected or in contact with such agents are called highly infectious waste.

TABLE 2.6 Categories and Classification of Hospital Waste.

WASTE CATEGORY	DESCRIPTION WITH EXAMPLES
Infectious waste	Pathogens may be present. E.g. excreta, laboratory cultures, tissues, materials or equipment that have been in contact with infected patient.
Pathological waste	Human tissues or fluids. E.g. Blood and other body fluids, fetuses.
Sharps	Sharp wastes. E.g. needles, knives, blades, broken glass infusion sets.
Pharmaceutical waste	Wastes containing pharmaceuticals. E.g. pharmaceuticals that are no longer needed or expired.
Genotoxic waste	Waste containing substances with genotoxic properties. E.g. waste containing cytostatic drug (often used in cancer therapy); genotoxic chemicals.
Chemical waste	Chemical substances present in a waste. E.g. laboratory reagents, film developer; disinfectants that are expired or no longer needed; solvent.
Wastes with high content of heavy metals	Batteries, broken thermometers, blood pressure gauges.
Pressurized containers	Gas cylinders, aerosol cans.
Radioactive waste	Radioactive substance present in a waste. E.g. unused liquids from radiotherapy or laboratory research, contaminate glassware, packages or absorbent paper.

2) Pathological waste

Pathological waste consists of tissues, organs, body parts, human fetuses and animal carcasses, blood and body fluids. Within this category, recognizable human or animal body parts are also called anatomical waste.

3) Sharps

Sharps are items that could cause cuts or puncture wounds, including needles, hypodermic needles, scalpel and other blades, knives, infusion sets, saws, broken glass and nails. These wastes are considered as highly hazardous even if they are infected or not.

4) Pharmaceutical waste

Pharmaceutical waste includes expired, unused, spilt and contaminated pharmaceutical products, drugs, vaccines and sera that are no longer required and need to be disposed of appropriately. The category also includes discarded items used in the handling of pharmaceuticals, such as bottles or boxes with residues, gloves, masks, connection tubing and drug vials.

5) Genotoxic waste

Genotoxic waste is highly hazardous and may have mutagenic and carcinogenic properties. It raises serious safety problems, both inside the hospital and outside after disposal. This category should be given serious and special attention, which includes certain cytostatic drugs, vomit, urine or feaces from patients treated with cytostatic drugs, chemicals and radioactive materials.

Cytotoxic (or antineoplastic) drugs, the principal substances in this category, have the ability to kill or stop the growth of certain living cells and are used in chemotherapy of cancer. They play an important role in the therapy of various neoplastic conditions but are also finding wider application as immunosuppressive agents in organtransplantation and in treating various diseases with an immunological basis. Cytotoxic drugs are the most often used in specialized departments such as oncology and radiotherapy units, whose main role is cancer treatment; however their use in other hospital departments is increasing and they may also be used outside the hospital setting.

Harmful *gyrostatic drugs* can be categorized as follows:

- alkylating agents: cause alkylation of DNA nucleotides, which leads to cross-linking and miscoding of the genetic stock;
- antimetabolites: inhibit the biosynthesis of nucleic acids in the cell;
- mitotic inhibitors: prevent cell replication

Cytotoxic wastes are generated from several sources and can include the following:

- contaminated materials from drug preparation and administration, such as syringes, needles, vials, packaging;
- outdated drugs, excess (leftover) solutions, drugs returned from the wards;
- urine, faeces and vomit from patiests, which may contain potentially hazardous amounts of their metabolites and which should be considered genotoxic for at least 48 hours and sometimes up to 1 week after drug administration.

In specialized oncological hospitals, genotoxic waste (containing cytostatic or radioactive substances) may constitute as much as 1% of the total health-care wastes.

6) Chemical waste

Chemical waste consists of discarded solid, liquid and gaseous chemicals, for example from diagnostic and experimental work and from cleaning, housekeeping and disinfecting procedures.

Chemical waste from health care may be hazardous or non-hazardous; in the context of protecting health, it is considered to be hazardous if it has at least one of the following properties:

- toxic
- corrosive (e.g. acids of $pH < 2$ and bases of $pH > 12$)
- flammable
- reactive (explosive, water-reactive, shock-sensitive)
- genotoxic (e.g. cytostatic drugs)

Non-hazardous chemical waste consists of chemicals with none of the above properties, such as sugars, amino acids and certain organic and inorganic salts. The types of hazardous chemicals used most commonly in maintenance of health-care centers and hospitals and the most likely to be found in waste are discussed in the following paragraph.

6.1) Formaldehyde

Formaldehyde is a significant source of chemical waste in hospitals. It is used to clean and disinfect equipment (e.g. haemodialysis or surgical equipment), to preserve specimens, to disinfect liquid infectious waste and in pathology, autopsy, dialysis, embalming and nursing units.

6.2) Photographic chemicals

Photographic fixing and developing solutions are used in X-ray departments. The fixer usually contains 5 to 10% hydroquinone, 1 to 5% potassium hydroxide and less than 1% silver. The developer contains approximately 45% glutaraldehyde. Acetic acid is used in both stop baths and fixer solutions.

6.3) Solvent

Wastes containing solvents are generated in various departments of a hospital, including pathology and histology laboratories and engineering departments. Solvents used in hospitals include halogenated compounds, such as methylene chloride, chloroform, trichloroethylene and refrigerants and non-halogenated compounds such as xylene, methanol, acetone, isopropanol, toluene, ethyle acetate and acetonitrile.

6.4) Organic chemicals

Waste organic chemicals generated from health establishments include:

- disinfecting and cleaning solutions such as phenol-based chemicals used for scrubbing floors, perchlorethylene used in workshops and laundries.
- Oil such as vacuum-pump oils, used engine oil from vehicles (particularly it there is a vehicle service station on the hospital premises)
- insecticides, rodenticides.

6.5) Inorganic chemicals

Waste inorganic chemicals consist mainly of acids and alkalis (e.g. sulfuric, hydrochloric, nitric and chromic acids, sodium hydroxide and ammonia solutions). They also include oxidants, such as potassium permanganate ($KmnO_4$) and potassium dichromate ($K_2Cr_2O_7$) and reducing agents, such as sodium bisulfite ($NaHSO_3$) and sodium sulfite (Na_2SO_3)

7) Wastes with high content of heavy metals

Wastes with high heavy-metal content represent a subcategory of hazardous chemical waste and are usually highly toxic. Mercury wastes are typically generated by spillage from broken clinical equipment but their volume is decreasing with the substitution of solid-state electronic sensing instruments (thermometers, blood pressure gauges, etc).

Whenever possible, spilled drops of mercury should be recovered. Residues from dentistry have high mercury content. Cadmium mainly comes from discarded batteries. Certain "reinforced wood panels" containing lead are still used in radiation proofing of X-ray and diagnostic departments. A number of drugs contain arsenic, but these are treated here as pharmaceutical waste.

8) Pressurized containers

Many types of gas are used in health care and are often stored in pressurized cylinders, cartridges and aerosol cans. Many of these, once empty or of no further use (although they may still contain residues), are reusable, but certain types-notably aerosol cans-must be disposed of. Whether inert or potentially harmful, gases in pressurized containers should always be handled with care; containers may explode it incinerated or accidentally punctured.

9) Radioactive waste

Ionizing radiations cannot be detected by any of the senses and-other than burns, which may occur in exposed areas-usually cause no immediate effects unless an individual receives a very high dose. The ionizing radiations of interest in medicine include the X-rays, α-and β-particles, and γ-rays emitted by radioactive substances. Radioactive waste includes solid, liquid and gaseous materials contamination with radionuclides. It is the produced as a result of procedures and tumour location and various investigative and therapeutic practices.

2.1.6.2 Hazard of Healthcare Waste

Exposure to hazardous health-care waste can result in disease or injury. The hazardous nature of health-care waste may be due to one or more of the following characteristics:

- it contains infectious agents
- it is genotoxic
- it contains toxic or hazardous chemicals or pharmaceuticals
- it contains sharps

2.1.6.3 Person at Risk

All individual exposed to hazardous health-car waste are potentially at risk, including those within health-care establishments that generate hazardous waste and those outside these sources who either handle such waste or are exposed to it as a consequence of careless management. The main groups at risk are the following:

- medical doctors, nurses, health-care auxiliaries and hospital maintenance personnel
- patients in health-care establishments or receiving home care
- visitors to health-care establishments

- workers in support services allied to health care establishments such as laundries, waste handling and transportation
- workers in waste disposal facilities (such as landfills or incinerators), including scavengers

The hazards associated with scattered, small sources of health care waste should not be over looked; waste from these sources includes that generated by home-based health-care, such as dialysis and that generated by illicit drug use.

2.1.6.4 Hazardous from Infectious and Sharps

Infectious waste may contain any of a great variety of pathogen micro - organisms. Pathogens in infectious waste may enter the human body by a number of routes:

- through a puncture, abrasion or in the skin
- through the mucous membranes
- by inhalation
- by ingestion

2.1.6.5 Impacts of Infectious Waste and Sharps

For serious virus infections such as HIV/AIDS and hepatitis B and C, hospital worker – particularly nurses-are at greatest risk of infection through injuries from contaminated sharps (largely hypodermic needles). Other hospital workers and waste management operators outside hospitals are also significant risk, as are individuals who scavenge on waste disposal sites (although these risks are not well documented).

The risk of this type infection among patients and the public is much lower. Certain infections spread through other media or caused by more resilient agents may pose a significant risk to the general public and to hospital patients.

Individual cases of accidents and subsequent infections caused by the hospital waste are well documented. For example; a hospital housekeeper in the USA developed staphylococcal bacteriaemia and endocarditis after a needle injury.

2.2 Literature review

2.2.1 Hospital Waste Stream Analysis

A waste stream analysis is a basis for identifying waste minimization options and establishing the degree of segregation. Hospital wastes can be classified into three categories. They include household waste (municipal solid waste), infectious waste, and hazardous waste. The rates of waste generation vary widely. One study of overall hospital waste found a range from 3.64-20.45kg/bed/day with an average of 10.45kg/bed/day. The typical breakdown of the overall hospital solid waste stream is as follows (Brunnet, 1996): general solid waste-56.4 percent, medical waste-17.5 percent, paper-3.1 percent, corrugated cardboard-10.9 percent, patient waste-8.5 percent, dry cell batteries –0.4 percent, wooden pallets – 0.4 percent, hazardous waste -2.0 percent, x-ray film-0.3 percent, and other-0.4percent .

Hospitals account for about 1 percent of all the municipal solid waste generated in the United States. The composition of hospital municipal solid waste is typically: 45 percent paper and paperboard, 15 percent plastic, 10 percent food waste, 10 percent metals, 7 percent glass, 3percent wood, and 10 percent other. A closer examination of this waste reveals that many items are recyclable materials amenable to waste minimization.

Regulated medical waste or infectious waste varies considerably in compositions and characteristics. The following ranges of bulk densities in pounds per cubic foot have been reported: human anatomical (50-75lb/ft^3); plastic (5-144); gauze, swabs and other cellulosic material (5-62); alcohol and disinfectants (48-62); sharps (400-500); and bedding (17.5-22.5). Shredded infectious waste has a bulk density of around 20 lbs per cubic feet but ranges widely from 10 to 150 lb/ft^3 depending on the composition.

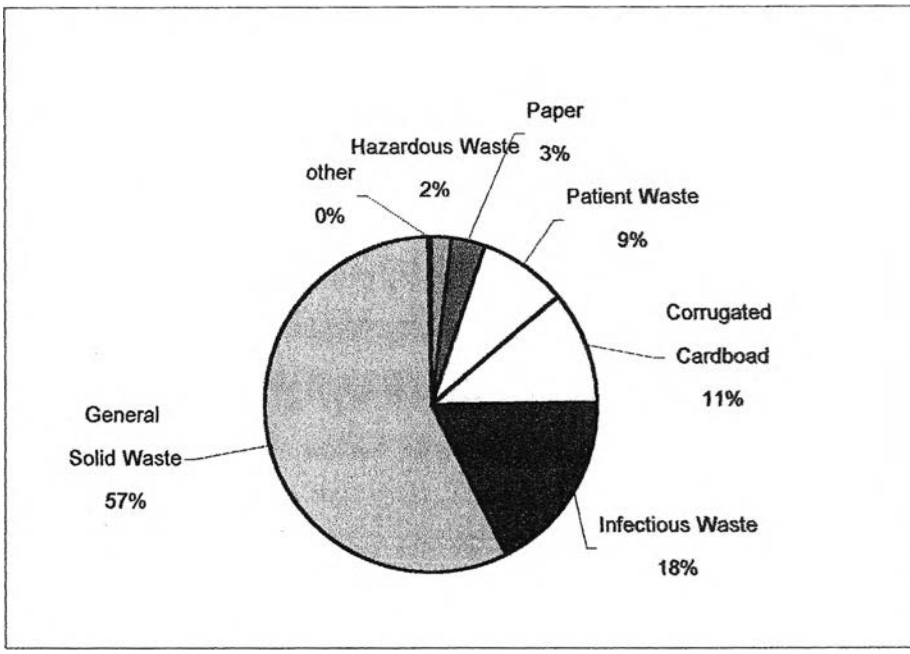

FIGURE 2.2: Breakdown of Typical Hospital Waste Stream (Bruuner,1996)

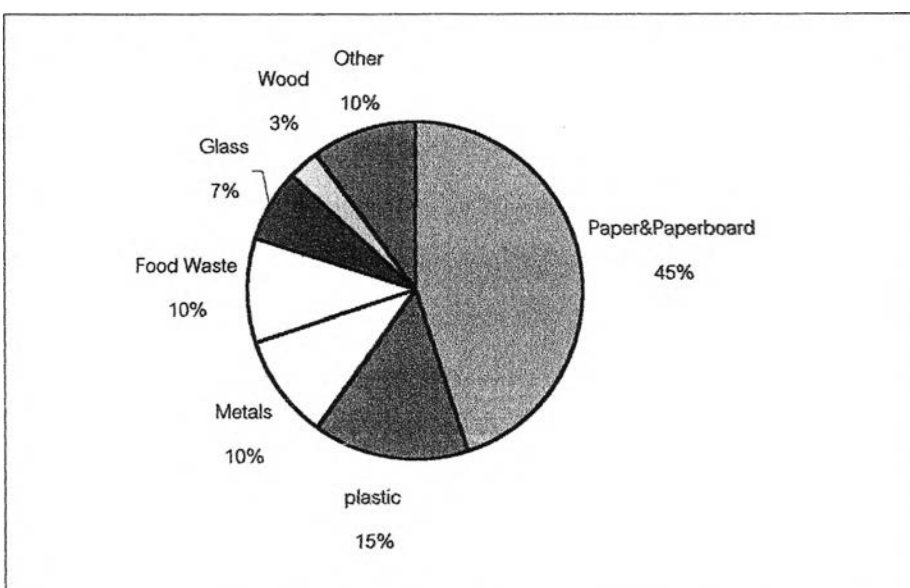

FIGURE 2.3: Hospital Solid Waste Composition (BIssan&Shaner, 1993)

TABLE 2.7 Result of a nationwide survey of U.S. Hospital, as reported by W.A.Rutala

BED SIZE	TOTAL WASTE kg/bed/day	TOTAL WASTE kg/patient/day	INFECTIOUS WASTE % of total waste
<100	2.59	5.13	13.3
100-299	4.70	7.16	15.0
300-499	5.67	8.63	14.9
>500	5.83	7.69	14.9
Total Avg	4.18	6.93	15.0

With regards to generation rates, the results of a nationwide survey of U.S. hospital, as reported by W.A. Rutala give a national average for infectious waste generation of 0.627kg/bed/day or 1.04kg/patient/day. These are useful; benchmark figures to help determine if a hospitals generating too much waste and could benefit from a vigorous waste minimization program.

Different types of hazardous wastes are generated at the health care facilities. Xylene, Methanol, and acetone are frequently used solvents. Other chemicals include toluene, chloroform, methylene chloride, trichloroethylene, ethanol, isopropanol, ethylene acetate, and acetonitrile. Formaldehyde wastes (formalin solutions) are found in pathology, autopsy, dialysis, nursing unit, emergency room, and surgery, among others. Chemotherapy wastes account for a large volume of hazardous waste in general hospital. One study found that hospitals, clinics, and surgery centers reported average ranges of chemotherapy waste from 13 to 69 percent of total waste produced.

The rate of waste generated in Thai hospitals situated in Bangkok, Pitsanulok, and Mahasarakam, were found to be varied from 0.16 to 0.93 kg/bed/day, depending on activities. Total waste from private hospital might be generated a higher amount

(1.25 kg/bed/day) compared to public hospital. However, private hospital seems to have a good management providing less infectious waste, around 0.12 kg/bed/day. In 2539, a survey in Khon Khean Hospital area found that trash bin covered only 47% of the total area. In addition, most collected sharp containers, around 96%, were plastic bottles found in hospitals. Approximately 43% of needles were taken of from syringes, while only 30% were covered needle before disposal. Needles with a brine recovery unit are another issue, and it was found that around 50% of users separate needle from the unit before disposal. According to these results, the hospitals had reported that some injuries by punctuation and stabbing were found at approximately 16%. Beside the collection problem, there is also a lack of basic treatment before disposal. It was found that there is no treatment of infectious waste, except for sharps. As reported in 2000 for general health care centers, infectious waste was produced with an average of 0.14-0.59kg/station/day depending up on the size of the station. Only 91% of infectious waste was collected in red plastic bags. The rest was collected with black plastic bag. Around 66% of containers were covered with lids. In case of sharps and needles, 53% of needles were segregate from infectious waste before disposal. Only 54% of the containers used to collect sharps and needles were strong enough to prevent the punctuation. However, some hospital provided machine to destroy needles particular. The report revealed that most officers were educated with a good level of understanding of infectious waste management. However, they still need a short-term practice in terms of waste classification and a needle-sharp collection system.

2.2.2 Hospital Waste Reduction

Waste prevention means eliminating waste before it is created. It's proven cost-effective approaches that help both your bottom line and environment. Combined with a comprehensive recycling effort, hospitals can significantly reduce their waste. Waste reduction Activities have been implemented by some hospital in the United States or have been provided by a medical professional. There are many ideas to help identify waste reduction opportunities at the hospital.

The Staten Island University Hospital embarked on a large-scale waste prevention program, targeting 56 waste prevention and energy conservation strategies for implementation at its North and South sites. Many of the strategies also address activities and procedures in place at some, or all of the clinics and other buildings operated by the hospital. Staten Island University Hospital initiated the waste prevention program in 1994 and adopted an Integrated Waste Management plan in August 1997. The following discussion summarizes highlights of the program.

Using 1995 activities as a baseline, the Hospital estimated its waste management costs, including costs associated with waste disposal contacts and waste disposal supplies (excluding labor) at $1,200,000. In1998, waste prevention efforts drove waste management costs down to a $721,167 level, reflecting a reduction of nearly $500,000 per year, relative to the 1995 costs. Between 1995 and 1998 waste quantities decreased from 6,912,000 pounds to 4,694,595 pounds per year. The quantity of Regulated Medical Waste (RMW) was reduced from 16% of total waste generation to 6.6% and recycling level increased from 6.4% to 9.5% of total waste generated. In addition to reducing its waste management operations costs, the hospital also has cut its electrical costs by more than $1,371,000 per year since 1994,by implementing effective energy conservation measures.

Calculating Waste Reduction: An estimated 6,912,000 pounds of waste requiring off-site disposal was generated by Staten Island University Hospital in 1995, when the hospital recycled 471,473 pounds of waste, a 6.4% recycling rate. In 1998 disposal requirements were reduced to 4,694,595 pounds per year, a reduction of 2,217,405 pounds, or 32% per year. Recycling also increased to 495,400 in 1998, for a 9.5% recycling rate. The combined decrease in off-site disposal and the increase in recycling resulted in an overall waste diversion of 39.9% from the 1995 baseline rate. This decrease includes the impact of the many individual departmental waste prevention initiatives.

2.2.3 Technology Considerations for Special HCW Treatment and Disposal

2.2.3.1 Technology Options

The choice of technology for waste treatment and disposal should always be driven by the objective of ***improving current health and environmental impacts.*** The technology choice should also be functional, safe, economically feasible, and sustainable. Choice of treatment/disposal technology needs to be made with cultural and religious sensitivities in mind. For example, in Hindu cultures, body parts should be cremated while in Muslim cultures, they should be buried below ground.

A basic principle in all waste management schemes is to segregate wastes as early as possible in the waste stream and to find the simplest solution for each type of waste. The first step in treatment and disposal is to ensure that all regular healthcare waste that can safely be sent to the normal municipal waste management system is managed in this way. The remaining wastes (special HCW) have characteristics that need particular treatment and disposal. A set of technical requirements for this treatment and disposal is provided in Table 2.8

TABLE 2.8: Technical Requirements for Treatment and Disposal of Special HCW

Elimination of hazardous characteristics of the wastes	▪ Destruction of viable infectious organisms ▪ Destruction of waste/used pharmaceuticals and medicines or transformation into harmless forms ▪ **Destruction of sharps and other materials capable of causing physical injuries** ▪ Final disposal or destruction of body parts, tissues, blood, and other organic material ▪ Transformation of wastes into unrecognizable or inoffensive forms
Controls on processes	▪ Assured long term performance in eliminating the hazardous characteristics ▪ Ability of the treatment and disposal system to cope with variations in waste composition and throughput
Environmental impacts of system	▪ Avoidance or minimization of secondary impacts from disposal system ▪ Prevention of human access and/or scavenging activities ▪ Control of contamination of land, air or water ▪ Avoidance of disease vectors (insects, rodents, etc.)

Source: ERM for World Bank

Controlled disposal in a sanitary landfill may be an acceptable disposal option for some types of special healthcare waste but other types should – in ideal conditions – be treated before disposal. In any case, final disposal in a landfill will usually be required for the residues from a treatment system.

Capability should also be carefully assessed when planning HCW disposition. Urban areas might have sophisticated incineration, sterilization, or disinfection technologies available, while rural areas might have limited options. When reviewing disposition plans, the technological standards are vital to a safe, appropriate plan. For instance, incineration may be considered when the incinerator can reliably reach temperatures over 1000 degrees (over 1200 degrees is necessary if burning sharps or infectious waste). Lower temperature incinerators produce greater amounts of toxic releases. Autoclave or microwave facilities may generate contaminated wastewater that needs treatment. Landfills should also be reviewed for appropriate liners and leachate collection systems, and should include ground water monitoring (if applicable). A reliable affordable local technological solution is preferable to infeasible (and therefore not implemented) solutions. A summary of treatment and disposal technologies is provided in Table 2.9. Table 2.10 indicates the performance of typical practices and treatment options in relation to the requirements of Table 2.8

TABLE 2.9 Treatment and Final Disposal Technologies for Special HCW

Type of treatment	Advantages	Disadvantages
Safe land filling: Trench method where healthcare waste is buried in a trench excavated in other waste (Final disposal)	- Simple and inexpensive to operate - No specific construction costs required - Operates within readily available landfill system - Waste pickers are unable to access the special healthcare waste	- Special healthcare waste is not treated and preserves potential infectiousness - High demand for coordination between collector and landfill operator - Reduces awareness among healthcare workers of need to segregate waste types.

Type of treatment	Advantages	Disadvantages
Safe land filling: Separate disposal cell (Final disposal)	Simple and relatively inexpensive to operate if operated in connection with existing landfill for other waste	Special healthcare waste is not treated and preserves potential infectiousness Requires a safe landfill with fencin
according to manual *Incineration :* 1) Batch incineration 2) Dual chamber, or 3) Rotary kiln (Destruction treatment)	- Elimination of health risks - The waste is non recognizable - Fully destroys micro organisms and sharps - Reduces volume/mass of the waste - Destroys all types of organic waste (liquids, pharmaceuticals, and other solids) - Heat recovery possible - High quantities of waste can be treated (except for batch incinerator) sophistication of the emission controls system	- High investment costs - Complicated to operate - Continuous monitoring required - High maintenance, especially for rotary kilns - Relatively high operation costs; costs rise with the level of - For batch incinerator: limited capacity - Emits toxic flue gases (including dioxins and furans; level varies) - Currently there is no accepted level of emission for dioxins and furans, however EU standards provide a good basis for comparison. - Generates residue that needs safe landfilling - Any residue generated may be toxic
Steam Disinfection: Autoclave (Sterilization)	- Simple to operate A known technology at healthcare facilities - Relatively expensive to install and operate	- Requires boiler with stack emissions controls - Relatively high maintenance costs - Cannot be used to treat some hazardous wastes, pharmaceuticals, and cytotoxics - Requires separate and additional packaging - Generates odors - Final disposal must be as for untreated special healthcare waste - Generates contaminated wastewater that needs treatment

Type of treatment	Advantages	Disadvantages
Microwave: Microwave or radiowave irradiation (Disinfection)	- The shredding process reduces the volume of the waste (not mass)	- Highly sophisticated and complex - Relatively expensive to install - Only solids can be treated and only when shredded - Cannot be used to treat some hazardous wastes, pharmaceuticals, and cytotoxics - Highly skilled operator required - Expensive and difficult to maintain - Final disposal must be same as for untreated special healthcare waste - Generates contaminated wastewater that needs treatment
Chemical treatment: (Disinfection)	- The shredding process reduces the volume of the waste (not mass)	- Cannot be used to treat some hazardous wastes, pharmaceuticals, and cytotoxics - Highly skilled operator required - Expensive and difficult to maintain - Final disposal must be same as for untreated special healthcare waste - Generates hazardous water that needs treatment

It must be emphasized that the advantages and disadvantages listed assume the proper operation of the described treatment methods.

TABLE2.10 Comparisons with Technical Requirements

(Broad comparisons, based on general experience – individual examples will vary)

	Typical Current Practice				**Typical Disposal Options – properly operated**				
	On-site dumps	**Open burning**	**Municipal dumps**	**On-site incineration**	**High temp. incineration**	**Autoclaving**	**Micro-waving**	**Chemical sterilization**	**Sanitary landfill**
Elimination of hazardous characteristic									
Destruction of infectious organisms	none	poor	none	Poor to moderate	Very good	good	good	good	good
Destruction of body parts, blood etc.	none	good	none	good	Very good	Poor to moderate	Poor to moderate	Poor to moderate	good
Destruction of waste pharmaceuticals	none	good	none	good	Very good	none	none	Poor to moderate	moderate to good
Destruction of sharps, etc	none	moderate	none	moderate	very good	Poor to moderate	Poor to moderate	moderate	moderate
Transformation of wastes	none	moderate	none	good	Very good	moderate	moderate	moderate	good
Controls on process:									
Assured Elimination of hazards	none	Very poor	none	Very poor	Very good	moderate	moderate	moderate	moderate
Ability to cope with variations	good	poor	good	poor	Very good	poor	poor	poor	good

	Typical Current Practice				Typical Disposal Options – properly operated				
	On-site dumps	Open burning	Municipal dumps	On-site incineration	High temp. incineration	Autoclaving	Micro-waving	Chemical sterilization	Sanitary land fill
Avoidance of secondary impact	poor	Very poor	poor	poor	Poor to moderate	Poor to moderate	moderate	Poor to moderate	Poor to moderate
Prevention of human access	moderate	moderate	Very poor	good	Very good	Very good	Very good	Very good	moderate to good
Prevention of contamination of land	Very poor	poor	Very poor	good	Very good	Very good	Very good	Very good	good
Avoidance of disease vectors	poor	Poor to moderate	Very poor	Very good	Very good	Very good	Very good	Very good	moderate

Direct disposal in a sanitary landfill may be the least expensive disposal option, if an acceptable landfill is located within reasonable transportation distance. However, some special healthcare wastes, such as cytotoxics, should not be put in a landfill. A dual chamber or rotary kiln incinerator can be used for treatment of this type of special healthcare waste. Pollution control systems (scrubbers, etc.) on incinerators are essential in order to avoid release of dioxins and other chemicals. The choice of an appropriate technology for treatment of the special wastes will depend on a range of local circumstances. Some examples are the state of the existing waste management system, the institutional capacity and the human resources available, and the costs of the different options in relation to the financial situation of the health sector.

A number of general comments can be made:

1) Incineration is not the same as burning. Proper incineration is a highly advanced technology that can adequately treat all types of special healthcare waste. The key parameters of controlled incineration are summarized as "TTT": combustion at a sufficiently high **temperature**

(between 1,000° C and 1,200° C in the combustion chamber) for a long enough **time**, in a combustion chamber with sufficient **turbulence** and oxygen for complete combustion to be achieved and problematic gases to be minimized.

An incinerator requires skilled operators, extensive flue gas emission controls and, frequently, imported spares and supplies. Properly controlled incineration is relatively expensive. Incineration of wastes generates residues, including air emissions and ash. Environmental controls on incinerators in developed countries have been tightened in recent years, principally because of concerns over air emissions of pollutants such as dioxins (see D.2) and heavy metals.

The technology of small-capacity incinerators, for use by a single medical facility, is often rudimentary. These installations are not recommended, since they may constitute a serious air pollution hazard to the surrounding area. WHO recommends closing down small incinerators that are not operating satisfactorily.

Incineration is an option for certain types of HCW (and is the preferred method for some substances such as cytotoxins and other pharmaceuticals) but it needs to be carefully operated and controlled. Regulatory agencies in the United States and the European Union have adopted emissions limits for medical waste incinerators that include, among others, values for dioxins. It is recommended that incinerators installed under any major project pay attention to national regulations and/or look to the examples set in other countries such as in the EU Member States.

2) Autoclaving involves the heating of waste material, with steam, in an enclosed container at high pressure. At the appropriate levels of time (> 60 min), temperature (>121° C), and pressure (100 kPa) effective inactivation of all vegetative microorganisms and most bacterial spores can be achieved. Preparation of material for autoclaving requires segregation to remove unsuitable material and shredding to reduce the individual pieces of waste to an acceptable size.

Small autoclaves are common for sterilization of medical equipment but a waste management autoclave can be a relatively complex and expensive system requiring careful design, appropriate segregation of materials, and a high level of operation and maintenance support.

The output from an autoclave is non-hazardous material that can normally be landfilled with municipal waste. There is also a wastewater stream that needs to be disposed of with appropriate care and controls. Furthermore, large autoclaves may require a boiler with stack emissions that will be subject to control.

At present, the use of autoclaving, chemical disinfection or any other non-destructive technology like microwave or radiowave irradiation is not allowed for the treatment of special HCW such as organs, tissues, or amputated human body parts. Incineration or burial are the only accepted techniques for the treatment of such special type of HCW.

3) Microwave and Radiowave Irradiation involves the application over the wastes of a high energy electromagnetic field that provokes the liquid contained within the waste, as well as the liquid cell material of microorganisms, to oscillate at high frequency, heat up rapidly, and eventually cause the destruction of all infectious components of the waste. The technique takes place in enclosed containers at atmospheric pressure and temperatures below the normal water boiling point. The waste passes through a preparative process of segregation to remove undesirable material, then it is triturated, pulverized, and compressed prior to its disinfection.

Similar to the autoclaving technique, the output from a microwave or radiowave facility is considered non-hazardous and can be landfilled together with municipal waste. Since the technology does not involve the application of steam, there is a minimal generation of wastewater stream, and with the appropriate conditioning it can be recycled to the system. Since electricity is the main source of energy for operating this technology, gas emissions are also minimal compared to incineration or even autoclaving, which requires the combustion of fuel for the generation of steam.

4) Chemical disinfection, used routinely in healthcare to kill microorganisms on medical equipment has been lately extended to the treatment of HCW. Chemicals (mostly strong oxidants like chlorine compounds, ammonium salts, aldehydes, and phenolic compounds) are added to the waste to kill or inactivate pathogens. This treatment is most suitable for treating liquid wastes such as blood, urine stools or hospital sewage, but solid and highly hazardous HCW like microbiological cultures, or sharps must undergo a relatively complex and expensive preparative process of segregation shredding, and milling prior to the application of the nchemical reagents. This technology requires special treatment of hazardous wastewater streams.

5) Land deposition of HCW is performed in the same manner as solid industrial wastes; that is, in a pit excavated in mature municipal waste at the base of the working face and immediately covered by a two-metre deep layer of fresh municipal waste. Alternatively , a specially constructed small fenced landfill pit or bunded area could be prepared on part of the site to receive only HCW. It should be covered immediately with soil after each load. For added health protection and odor suppression, it is suggested that lime be spread over the waste. In both cases it is essential to cover the HCW layer well enough to prevent animals or scavengers from re-excavating it. Landfilling is considered as a "bottom of the list" option for disposal of HCW, and is only recommended when the economic situation of the country does not permit access to environmentally safer technologies, such as the ones previously described.

Other technical issues:

1) Transport of special healthcare waste on public roads is inevitable under any system designed to treat and dispose of special healthcare waste outside the generating premises. Transportation of special healthcare waste should, as a minimum, be carried out by trained staff in a dedicated vehicle with closed containers. Recommended design criteria for special healthcare waste transportation vehicles are provided in the WHO handbook.

2) Operation and maintenance of equipment and facilities is essential for proper waste management. Good operation and maintenance requires trained and motivated staff, an adequate supply of consumables and spares, and a sufficient ongoing budget. Assessment of these matters must be a fundamental part of any decisions on choice of waste management treatment technology.

2.2.3.2 Cost Considerations for Waste Treatment and Disposal

The cost of investments in waste treatment and disposal varies dramatically depending on the waste quantity and quality, treatment method to be implemented, and capacity of the treatment facility. The capital costs indicated in the tables below are exclusive of shipment costs and of buildings required for the treatment facilities. These factors depend on local conditions; and the respective costs are often marginal in comparison with the costs for the treatment equipment. Further, technical assistance is required including contributions from the following specialists: supervision and quality assurance/control; and site engineer.

TABLE 2.11 Estimates of Capital Costs per Ton of Treatment Capacity/Various Treatment Options

Treatment method	Approximate investment cost per ton of special healthcare waste treatment capacity per day [US$/ton/day] (in 1999 prices)
Landfill [1]	-
Incineration including flue gas control	120,000-200,000
Autoclaving	40,000-125,000
Irradiation (Microwave)	120,000-200,000

[1/] There is no initial cost for the healthcare facility, since the investment cost required for landfills is reflected in the tipping fee. Tipping fees in developing countries often range from 8-15 US$/ton.

TABLE 2.12 Treatment and Disposal Costs per Ton of Special HCW/Selected Countries

	Treatment/disposal costs for special healthcare waste in US$/ton
Malaysia	2,080 [1/]
Denmark	200-350
Egypt	150
France	150-500
Germany	500-1500
Brazil	186 1530 [2/]
United Kingdom	200-500
Argentina	630-16710
Mexico	410-750
USA	280-420

[1/] This price includes collection at healthcare facility, transportation, and treatment. Malaysia has found the average amount of special healthcare waste generated is 0.7kg/bed/day.
[2/] Higer cost of US$1530/ton corresponds to a system of mobile incineration utilized in Curitiba

TABLE 2.13 Average Treatment and Disposal Costs for Special HCW/Selected Cities

City	**Disposal costs in US$/bed/day**
Curitiba/Brazil	0.26
Mexico City/Mexico	0.96 [2/]
Buenos Aires/Argentina	0.76 [3/]
Melaka/Malaysia	1.45 [1/]

[1/] This price includes collection at healthcare facility, transportation, and treatment. Malaysia has found the average amount of special healthcare waste generated is 0.7kg/bed/day.
[2/] At an average generated HCW of 1.48 kg/bed/day.
[3/] At an average generated HCW of 1.2 kg/bed/day